VALIDITY OF A SMART GARMENT TO COLLECT MEASURES OF HEART RATE VARIABILITY DURING REST AND POST-EXERCISE RECOVERY

2023 NSCA NATIONAL CONFERENCE

UMASS LOWELL

David J. Cornell,[1,2] Thomas J. Sherriff,[1,2] Quentin J. Proulx,[1,2] Donald W. Rogers,[1,2] Megan T. Duong,[1,2] Julia J. Hill,[1,2] Andreas T. Himariotis[1,2]

[1]Health Assessment Laboratory, [2]Department of Physical Therapy & Kinesiology, University of Massachusetts Lowell, Lowell, MA

INTRODUCTION

- Wearable technology allows the collection of various physiological measures including heart rate variability (HRV)[1,2]
- Wearable technology, such as watches, and straps have been validated,[3-6] but may not be comfortable or feasible to wear over long periods of time, indicating a need to develop a new wearable technology that overcomes these limitations
- A new smart garment prototype embedded with laminate electrocardiography (ECG) electrodes has recently been developed, which may provide a more feasible method of HRV assessment (Figure 1)
- However, the concurrent validity of this novel garment to an industry standard heart rate monitor (HRM) is unknown


Figure 1: Laminated Garment


Figure 2: Industry-standard HRM


Figure 3: Treadmill protocol

PURPOSE

- Thus, the ***purpose*** of this study was to determine the concurrent validity of a smart garment when collecting HRV data during rest and post-exercise recovery conditions

ACKNOWLEDGMENTS

We would like to acknowledge funding support from the Massachusetts Manufacturing Innovation Initiative of the Commonwealth of Massachusetts. We would also like to thank Human Systems Integration, Inc. for their collaboration and providing smart garments for this study, as well as the U.S. Army Research Institute for Environmental Medicine for their technical support.

METHODS

Participants

- 16 males participated in this study (age: 24.6 ± 4.3 yrs; height: 180.7 ± 6.7 cm; body mass: 88.0 ± 10.0 kg)

Protocols

- A HRM was first placed to avoid any interference with the laminate ECG electrodes (Figure 2) and then participants were fitted with the appropriately sized smart garment based on the chest circumference at their xiphoid process
- Participants then completed a treadmill exercise protocol (Figure 3) with HRV data collected before and after during the following conditions:
  - Resting – Supine (5 minutes)
  - Resting – Seated (5 minutes)
  - Recovery – Seated (5 minutes)
  - Recovery – Supine (5 minutes)

Data Processing

- R-R interval data (ms) were collected via a Polar H10 HRM paired with a Polar V800 watch (Polar Electro, Kempele, Finland) at a rate of 1,000 Hz[6] and the novel smart garment (TacMON, Human Systems Integration, Inc., Walpole, MA) at a rate of 250 Hz during Resting and Recovery conditions
- Raw R-R interval data were extracted from the HRM and smart garment and data from both the garment and HRM were processed using Kubios HRV 3.5 software (Kubios, Ltd., Kuopio, Finland) using an automatic correction filter[7] to calculate measures of HRV:
  - R-R interval (ms)
  - natural log of the root mean square of successive R-R interval differences (lnRMSSD) (ms)

Statistical Analyses

- Paired *t*-tests examined absolute agreement in HRV measures collected between devices
- Hedges' *g* effect sizes determined the magnitude difference[8] and were interpreted as:[9]
  - *very large*: $g \geq 2.0$; *large*: $2.0 > g \geq 1.2$; *moderate*: $1.2 > g \geq 0.6$; *small*: $0.6 > g \geq 0.2$; *trivial*: $g < 0.2$
- Bivariate Pearson correlations (r) and coefficient of determinations (R^2) were utilized to determine the level of association and variance shared in HRV measures collected between devices[8] and were interpreted as:[10]
  - *nearly perfect*: $r \geq 0.9$; *very strong*: $0.9 > r \geq 0.70$; *strong*: $0.70 > r \geq 0.50$; *moderate*: $0.50 > r \geq 0.30$; *small*: $0.30 > r \geq 0.10$; and trivial: $r < 0.10$
- An alpha of 0.05 determined statistical significance

RESULTS

- *Trivial* to *small* and non-significant ($p > 0.05$) differences in R-R interval and lnRMSSD data were observed between the smart garment and the HRM during the Resting – Supine, Resting – Seated, and Recovery – Supine conditions (Table)
  - However, a *moderate* and significant difference was observed in lnRMSSD data during Recovery – Seated position ($p = 0.011$) (Table)
- In addition, *very strong* to *nearly-perfect* and statistically significant ($p < 0.05$) correlations were identified between the smart garment and HRM in R-R interval data during the Resting – Supine ($r = 0.999$, $R^2 = 0.998$), Recovery – Seated ($r = 0.902$, $R^2 = 0.814$), and Recovery – Supine ($r = 0.759$, $R^2 = 0.576$) conditions, along with *very strong* to *nearly-perfect* correlations in lnRMSSD data during the Resting – Supine ($r = 0.985$, $R^2 = 0.970$) and Recovery – Supine ($r = 0.704$, $R^2 = 0.496$) conditions
  - However, only *strong* correlations in R-R interval data and lnRMSSD data were identified between the smart garment and HRM during the Resting – Seated ($r = 0.658$, $R^2 = 0.433$; $r = 0.608$, $R^2 = 0.370$, respectively) condition
  - Further, only a *strong* correlation in lnRMSSD data was identified between the smart garment and HRM during the Recovery – Seated ($r = 0.529$, $R^2 = 0.280$) condition

TABLE. Comparisons Between Smart Garment and HRM (mean ± *SD*).*

Condition	Smart Garment	HRM	Mean Difference	Effect Size	Data Loss
R-R Interval Data (ms)					
Resting – Supine (n = 14)	955.37 ± 146.70	956.99 ± 146.86	-1.63 ± 3.19	g = 0.01 *trivial*	12.5% (2/16)
Resting – Seated (n = 15)	833.43 ± 130.01	871.30 ± 100.18	-37.87 ± 98.98	g = 0.33 *small*	6.25% (1/16)
Recovery – Seated (n = 15)	591.57 ± 68.64	599.76 ± 75.55	-8.19 ± 32.68	g = 0.11 *trivial*	6.25% (1/16)
Recovery – Supine (n = 14)	682.70 ± 84.12	698.20 ± 85.13	-15.51 ± 58.70	g = 0.18 *trivial*	12.5% (2/16)
lnRMSSD Data (ms)					
Resting – Supine (n = 14)	4.14 ± 0.65	4.13 ± 0.61	+0.004 ± 0.12	g = 0.02 *trivial*	12.5% (2/16)
Resting – Seated (n = 15)	4.24 ± 0.81	3.96 ± 0.45	+0.28 ± 0.64	g = 0.43 *small*	6.25% (1/16)
Recovery – Seated (n = 15)	3.25 ± 1.32	2.41 ± 0.73	**+0.85 ± 1.12**†	g = 0.79 *moderate*	6.25% (1/16)
Recovery – Supine (n = 14)	2.81 ± 1.16	2.51 ± 0.83	+0.31 ± 0.82	g = 0.30 *small*	12.5% (2/16)

*HRM, heart rate monitor; lnRMSSD = natural log of the root mean square of successive R-R interval differences.
†Significant difference between smart garment and HRM devices via paired t-tests ($p < 0.05$).

CONCLUSIONS

- The smart garment prototype demonstrated concurrent validity with collecting R-R interval data during rest and post-exercise recovery, but the degree of validity decreased after exercise in the seated position

PRACTICAL APPLICATIONS

This novel smart garment prototype may prove to be an effective method for strength and conditioning professionals to assess HRV measures for longer periods of time and in a variety of field-based environments

REFERENCES

1. Singh N, Moneghetti KJ, Christle JW, et al. *Arrhythm Electrophysiol Rev.* 2018;7(4):247-255.
2. Singh N, Moneghetti KJ, Christle JW, et al. *Arrhythm Electrophysiol Rev.* 2018;7(3):193-198.
3. Nazari G, Bobos P, MacDermid JC, et al. *BMC Sports Sci Med Rehabil*. 2015;10:6.
4. Villar R, Beltrame T, Hughson RL. *Appl Physiol Nutr Metab*. 2015;40(10):1019-1024.
5. Akintola AA, van de Pol V, Bimmel D, et al. *Front Physiol.* 2016;7:391.
6. Caminal P, Sola F, Gomis P, et al. *Eur J Appl Physiol*. 2015;118(3):669-677.
7. Tarvainen MP, Niskanen JP, Lipponen JA, et al. *Comput Methods Programs Biomed.* 2014;113(1):210-220.
8. Lakens D. *Front Psychol.* 2013;4:863.
9. Hopkins WG, Marshall SW, Batterham AM, et al. *Med Sci Sports Exerc*. 2009;41(1):3-13.
10. Schober P, Boer C, Schwarte LA. *Anesth Analg*. 2018;126(5):1763-1768.